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USER MANUAL: INTERIM PROCEDURE FOR PLANNING ROTARY-WING AIRCRAF--ETC(
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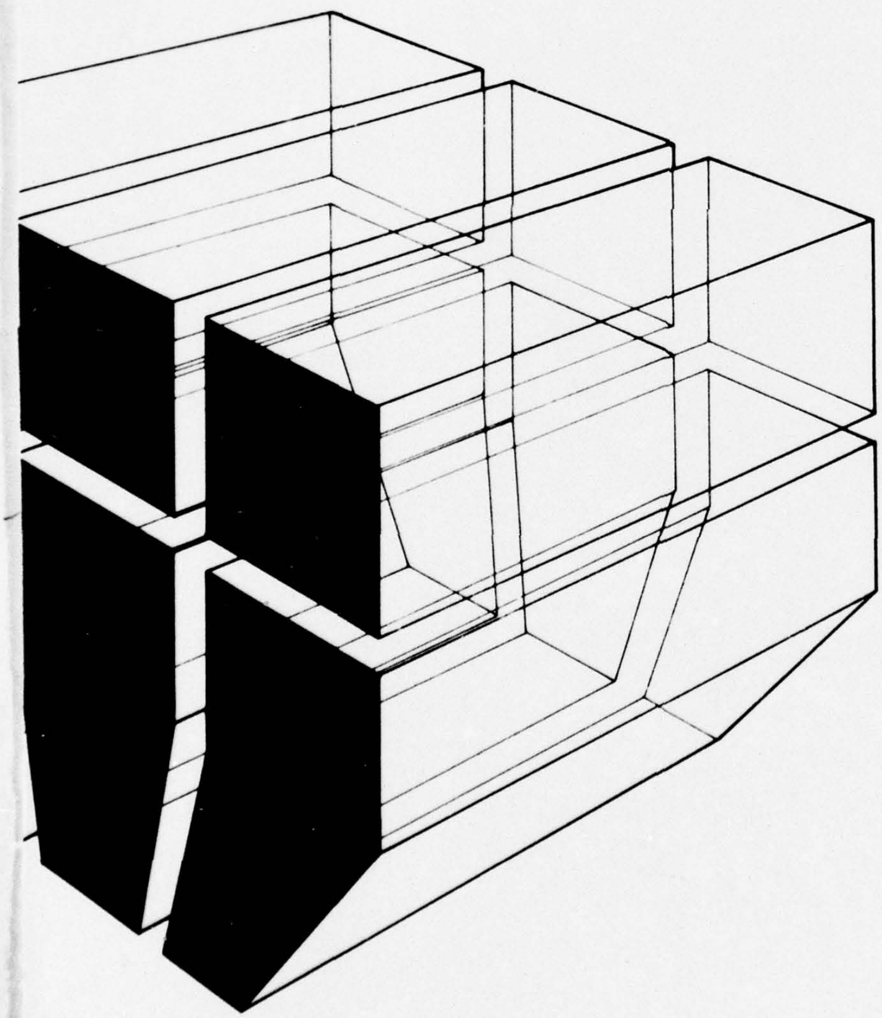
INTERIM REPORT N-10
September 1976
Prediction and Reduction of the Noise Impact Within and Adjacent to Army Facilities

USER MANUAL: INTERIM PROCEDURE FOR PLANNING ROTARY-WING AIRCRAFT TRAFFIC PATTERNS AND SITING NOISE-SENSITIVE LAND USES

by
P. D. Schomer
B. L. Homans



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This report presents (1) interim procedures for determining the location of rotary-wing aircraft traffic patterns and ingress and egress corridors into an airfield/heliport area to avoid conflict with noise-sensitive land uses, and (2) criteria for siting noise-sensitive land uses with respect to established airfield or heliport plans. The procedures are based on interim criteria established in a companion report, *Technical*

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Background: Interim Criteria for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses (Construction Engineering Research Laboratory Interim Report N-9, 1976). The presentation of the procedures includes a history of noise impact measures, a background of the development of noise contours, and tables for finding the noise impact. A complete descriptive example of the use of the procedures is presented as an aid to the reader.

FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task 02, "Pollution Control Technology"; Work Unit 008, "Prediction and Reduction of the Noise Impact Within and Adjacent to Army Facilities." The QCR number is 1.03.001.

Mr. F. P. Beck is the OCE Technical Monitor. Guidance was provided by Mr. J. L. Halligan of OCE.

This study was conducted by the Acoustics Team (Dr. P. D. Schomer, Acting Chief) of the Environmental Division (Dr. R. K. Jain, Chief), U.S. Army Construction Engineering Research Laboratory (CERL).

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Deputy Director.

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REFERENCES

Air Installations Compatible Use Zones, DOD Instruction 4165-57 (Department of Defense).

Construction Criteria Manual, DOD 4270.1-M (Department of Defense).

Fliakas, P. J., Deputy Assistant Secretary of Defense, Installations and Housing—ID, *Air Installations Compatible Use Zone Noise Descriptors,* letter of 15 October 1975.

Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety, Report 550/9-74-004 (Environmental Protection Agency, 1974).

Schomer, P. D. and B. L. Homans, *Technical Background: Interim Criteria for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses,* Interim Report N-9 (Construction Engineering Research Laboratory [CERL], 1976).

1 INTRODUCTION

Background

Urban development has been encroaching on military and civilian airfields in recent years. In particular, residential development has been occurring in areas subject to high noise levels which emanate from aircraft and airfield operations. The Army has an obligation to protect the well-being and safety of persons and property in Army airfield environments as well as to use public funds judiciously in constructing facilities near airfields.

Since the prediction of rotary-wing aircraft noise impact is still under development, criteria which permit easy interpretation of existing published guidelines are needed. The *Construction Criteria Manual* and the *Air Installation Compatible Use Zones* are two Department of Defense (DOD) documents that define land-use restrictions. Both documents describe three zones which impose varying degrees of restriction on land use in order to insure its compatibility with the characteristics of Army operations. A third document, the 15 October 1975 letter from the Installations and Housing Deputy Assistant Secretary of Defense, subject: *Air Installations Compatible Use Zone Noise Descriptors,* amends the first two references to include a correction to meter readings for helicopter noise as well as use of the Day-Night Equivalent Level (L_{dn}, described in Chapter 2) as a descriptor.

Purpose

The purpose of this report is to establish interim* procedures based on criteria established in a companion report, *Technical Background: Interim Criteria for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses.* These procedures can be used to determine the location of rotary-wing aircraft traffic patterns and ingress and egress corridors into an airfield or heliport area to avoid conflict with noise-sensitive land uses, and to provide criteria that enable planners to site noise-sensitive land uses with respect to an established airfield or heliport. The operations plan established using these criteria will define areas where helicopter noise may or may not be a problem. Implementation of this plan will insure compatible development and future unimpeded airfield capability.

2 EVOLUTION OF NOISE IMPACT MEASURES

Measurement of Noise Impact

Several measures of noise impact have historically been used for aircraft noise. This section describes the three most significant ones used in the United States—Composite Noise Rating, Noise Exposure Forecast, and Day-Night Equivalent Level.

The Composite Noise Rating (CNR), conceived in about 1952, was the first attempt at evaluating community noise. In its present form, Perceived Noise Level (PNL) tables and graphs are used to derive a noise rating and the expected community response. These tables and graphs are available for fixed-wing aircraft but, due to the present state of helicopter

*A more detailed procedure for use in highly complex operations and in situations of great impact is currently being developed at the Construction Engineering Research Laboratory (CERL).

prediction, not for rotary-wing aircraft. Results of tests for rotary-wing aircraft will be available in the near future.

The PNL tables and graphs, along with three corrections for environmental conditions, are used in the calculation of CNR. These corrections are: (1) weighting for the time of day (daytime 0700 to 2200 hrs, and nighttime 2200 to 0700 hrs), (2) seasonal adjustment, and (3) the number of aircraft operations (with average duration assumed).

The Noise Exposure Forecast (NEF) was conceived in 1967 based on new data and further study of CNR, as a better expression of aircraft classification and performance. The Effective Perceived Noise Level (EPNL), a much more complicated computation than PNL, is used as the basic noise measure in calculating NEF.

Along with EPNL data, number of operations per day and night is also used as input for NEF. As in CNR, a penalty of 10 dB is added for nighttime operations. That is, for the same average number of aircraft operations per hour during the daytime and nighttime periods, the NEF value for nighttime operations is 10 dB higher than for daytime operations. Finally, the calculated NEF values around a given airfield are lowered in absolute value by subtracting a constant (88) to avoid confusion with other noise measures such as CNR.

The Day-Night Equivalent Level (L_{dn}) was developed to provide a single-number measure of time-varying noise for a specified time period. In other words, L_{dn} uses the energy equivalent concept, which represents a fluctuating noise level in terms of a steady-state noise having the same amount of total energy. The specified integration time is 24 hours.

In a similar although not absolutely equivalent fashion to CNR and NEF, L_{dn} applies a 10-dB correction to account for the increased annoyance due to noise during the night hours. The noise level is measured in A-weighted sound pressure level.

The Environmental Protection Agency (EPA) has chosen, and DOD has accepted, L_{dn} as the best measure for situations where people are affected by noise for extended periods of time. It is recognized that L_{dn} is not necessarily the best measure for impulsive noise. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*, commonly known as the "EPA Levels Document," provides more information on L_{dn} and how it is used.

Definitions of Terms

1. AGL—Above Ground Level.

2. Conflict with a noise-sensitive land use—A day-night equivalent level (L_{dn}) in excess of 65.

3. Ground distance—Distance along the ground measured from the projection of the aircraft on the ground to the observer (Figure 1).

4. Ingress and egress corridors—Approach and departure corridors (and other traffic corridors) where flight altitudes are less than the altitude AGL required to maintain a day-night equivalent level not exceeding 65.

5. L_{dn}—Day-night equivalent level is the average (on an energy basis) A-weighted noise level integrated over a 24-hour period (weighted for time of day).

6. NEF—Noise Exposure Forecast is the total summation (on an energy basis) over a 24-hour period (weighted for time of day) of Effective Perceived Noise Level minus the constant 88.

7. Noise-sensitive area—Areas including one or more of the following: bachelor and family housing, temporary lodging, recreation, welfare and religious facilities designed for the assembly of groups of people, and medical facilities. Additionally, the Department of the Army includes school buildings.*

8. Operations

   a. In a traffic pattern, an operation is a takeoff or landing.

   b. In a corridor, an operation is a fly-by.

   c. Touch-and-go operations are counted as two operations.

9. Slant distance—The distance measured from the closest edge of the noise-sensitive facility to the center of the corridor (Figure 1).

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*This procedure should not preclude siting a school in a noise-sensitive area when the school subject relates directly to the noise source, such as a pilot-training classroom at an airfield. Proper acoustical considerations must be incorporated into the design of the school.

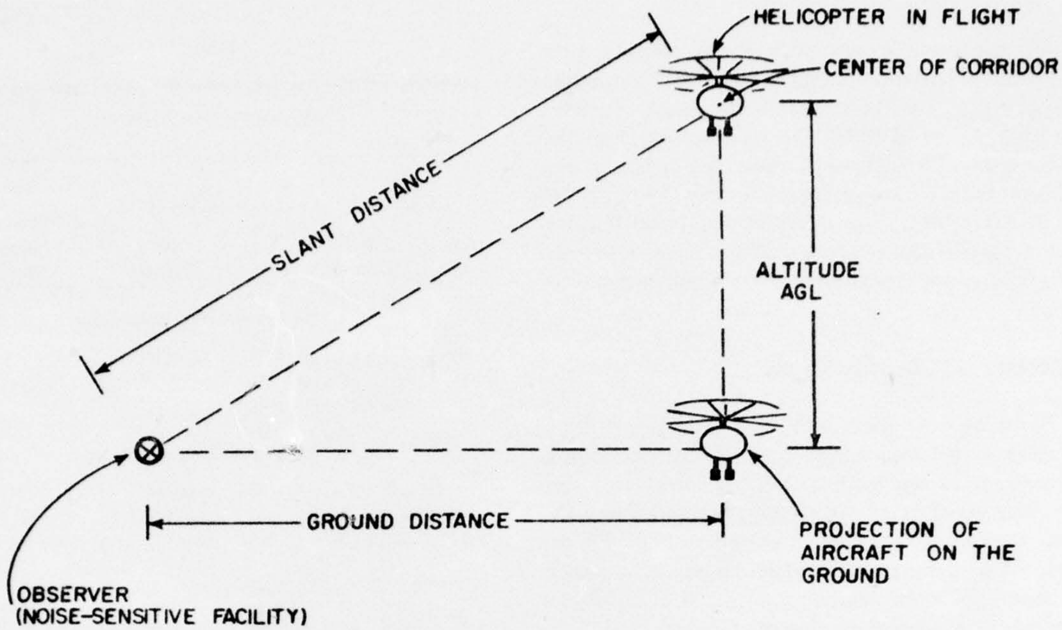

Figure 1. Illustration of the terms "ground distance" and "slant distance."

10. Planning slant distance—The recommended slant distance which would insure that the noise sensitive facility would not be subjected to an L_{dn} level of greater than 65.

3 DEVELOPMENT OF NOISE CONTOUR SYSTEM

Approach

CERL developed distance criteria for the placement of family housing and other noise-sensitive land uses from rotary-wing aircraft patterns in *Interim Criteria for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses.* Operational data used in the calculations to establish these criteria were the average operations at a typical airfield. Total number of operations, percentage of nighttime operations, and fleet mix were considered, as in any prediction methodology.

The DOD Air Installations Compatible Use Zones (AICUZ) Instruction describes three zones of noise impact. Zone 3, the smallest in area, has the largest noise impact on people and is the area in which the frequency of exposure and intensity are almost certain to produce difficulties in relation to some other possible uses of the area, particularly where the use or proposed use is residential. Zone 2 is a larger area in which similar problems with regard to other uses may occur. Zone 1, all land outside Zone 2, is an area in which essentially no such difficulties may be expected. NEF values above 40 and L_{dn} values above 75 are considered to be in Zone 3; values of 30 through 40 NEF or 65 through 75 L_{dn} in Zone 2; and values below 30 NEF or 65 L_{dn} in Zone 1.

The DOD *Construction Criteria Manual* recommends that bachelor and family housing, temporary lodging, recreation, welfare and religious facilities designed for the assembly of groups of people, and medical facilities be sited in Zone 1. In addition, the Army includes school buildings in Zone 1.*

The 15 October 1975 DOD letter, subject: *Air Installations Compatible Use Zone Noise Descriptors* amends the above two references. One change is to compute L_{dn} in place of CNR or NEF. The other is a recommended correction of +7 dB to be added to meter readings when helicopter noise levels are measured.

*This procedure should not preclude siting a school in a noise-sensitive area when the school subject relates directly to the noise source, such as a pilot-training classroom at an airfield. Proper acoustical considerations must be incorporated into the design of the school.

Two measures of noise impact were calculated for a variety of distances. NEF is the total summation (on an energy basis) over a 24-hour period (weighted for time of day) of EPNL (a single-number measure of complex aircraft flyover noise which approximates laboratory annoyance responses) minus the constant 88 dB. Day-Night Equivalent Sound Level (L_{dn}) is the average (on an energy basis) noise level (A-weighted sound level) over a specified amount of time.

Operational Considerations

In setting distance criteria for rotary-wing aircraft pattern usage, total number of aircraft operations, percentage of night operations, and fleet mix were considered, as in any prediction methodology. The total number of operations was chosen to be 100 per day. This number was made larger than traffic encountered in the normal pattern, *but it is felt that a larger than normal number of operations should be specified to allow for further growth.* Table 1 gives NEF and L_{dn} values for greater numbers of operations.

The percentage of nighttime rotary-wing operations was chosen to be 10 percent. Previous experience indicates that this figure accurately describes operations between 2200 and 0700 hrs at the typical airfield. It should be noted that increasing nighttime operations to 20 percent or lowering them to 1 percent would raise or lower the noise impact by only about 2 NEF or L_{dn} units.

The last of the general considerations—fleet mix—approximates ownership of aircraft by the Army. Since the missions of most airfields are dissimilar, a typical fleet mix was difficult to arrive at. A mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s was determined to be sufficient. Changes in this mix, e.g., to 40 percent UH-1s, 40 percent OH-58s, 15 percent AH-1Gs, and 5 percent CH-47s would affect the noise impact only slightly.

Applicability of Method

The method for calculating noise impact is also applicable for predicted or projected operations. If a new unit is being assigned to the airfield, the numbers of operations for the activities concerned may be boosted. This may require that new corridors be created or existing ones be either widened and/or increased in altitude to handle the increased traffic. If the specific change in operations is not known, then as a first try, all operations may be increased to reflect the anticipated total.

Table 1

Calculated NEF and L_{dn} Values With Corresponding Slant and Planning Slant Distances*

NEF		L_{dn}		
NEF	Slant Distance	L_{dn}	Slant Distance	Planning Slant Distance
a. 100 Average Daily Operations				
40	350 ft (107 m)	75	300 ft (91 m)	325 ft (99 m)
35	850 ft (259 m)	70	750 ft (229 m)	800 ft (244 m)
30	1800 ft (549 m)	65	1800 ft (549 m)	1800 ft (549 m)
b. 150 Average Daily Operations				
40	550 ft (183 m)	75	400 ft (122 m)	475 ft (152 m)
35	1100 ft (335 m)	70	1100 ft (335 m)	1100 ft (335 m)
30	2300 ft (701 m)	65	2500 ft (762 m)	2400 ft (732 m)
c. 200 Average Daily Operations				
40	650 ft (198 m)	75	500 ft (152 m)	575 ft (175 m)
35	1300 ft (396 m)	70	1400 ft (427 m)	1350 ft (411 m)
30	2900 ft (884 m)	65	3000 ft (914 m)	2950 ft (899 m)
d. 300 Average Daily Operations**				
40	800 ft (244 m)	75	750 ft (213 m)	775 ft (236 m)
35	1900 ft (579 m)	70	1800 ft (549 m)	1850 ft (564 m)

*Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

**This procedure is not intended for extremely large numbers of operations, such as 300 or more. CERL should be consulted before applying these criteria in such cases.

Corridors should be created for the anticipated maximum average daily number of operations. Table 1 shows recommended planning distances versus L_{dn} and NEF established for 100, 150, 200, and 300 operations per day. It is felt that 100 is the minimum number of operations that should be used for planning purposes when actual daily operations exceed 10. Less than 10 operations per day should be ignored when not associated with any activity that has fair growth potential. The lower limit of 10 operations per day is designed to allow landing pads at the hospital or the base headquarters to be excluded from the planning requirements.

This limit notwithstanding, patterns associated with main airfield operations in the vicinity of the

airfield itself must be assessed using the 100-operation minimum number. When actual operations approach 100 or more, a higher operational range should normally be used so that an allowance is made for future growth and mission change.

4 PROCEDURE FOR GENERATING NOISE IMPACT CONTOURS

This section provides the means for generating noise impact contours for a typical rotary-wing airfield. Included is a step-by-step procedure covering acquisition of operational data, layout of corridors and zones, calculation of operations, description of altitude profiles, separation of corridors and zones, and calculation of noise impact. In the typical situation, two sets of contours (L_{dn} 65 and 75 or NEF 30 and 40) are usually calculated. When more detail is required, L_{dn} 70 (NEF 35) may also be included. Since one set of contours is sufficient for explanation of the procedure, L_{dn} 70 was chosen to be calculated throughout this section.

A fictitious Base X is used to illustrate the prescribed procedure. Any resemblance between this base and any government facility, active or inactive, is purely coincidental. Figures are also included to clarify each step of the procedure.

Although the discussion concerns present operations at the base, the method for calculating noise impact is equally applicable for predicted or projected operations.

Acquisition of Operational Data

Number of events is an important part of any prediction method. This section examines and illustrates an easily implemented method for acquiring rotary-wing aircraft operational data.

At Base X's control tower, records were previously kept that exhibited the total number of rotary- and fixed-wing aircraft operations per month. Since a more detailed accounting of aircraft improves the accuracy of the noise assessment, Base X implemented daily tabulation of total aircraft operations at the airfield. DA Form 1968-R (Figure 2) illustrates a typical log kept by the flight control tower personnel. These data, when purged of communication counts, will provide the operational helicopter activity count for the specific airfield or heliport. These data should be augmented by the following:

1. Time of day (0700 to 2200 or 2200 to 0700 hrs)
2. Type of helicopter
3. Direction of approach or departure
4. Helicopter traffic corridor used
5. Destination or point from which flight originated.

Wind direction is frequently a good indicator of the direction of flight, since helicopters land and take off into the wind. A wind rose for the airport or heliport should be on the airfield or heliport map. Knowing percentages for wind direction enables one to infer that the same percentage of total operations flew in a certain direction or used a particular route. This has been found to be a fairly accurate method which correlates well with actual observations.

Operations conducted at each runway and helipad must be known before further steps can be taken to calculate noise impact. Examination of each runway and helipad at the fictitious airfield will illustrate the necessary information. A sketch of the base showing training areas is included in Figure 3.

Runway 9-27 is used exclusively for fixed-wing aircraft and will not be dealt with at this time.

The parallel taxiway (paralleling runway 9-27) handles approximately one-fourth of the airfield's rotary-wing traffic. The main use of this taxiway is for rotary-wing practice touch-and-go's which use a single traffic pattern to the south. (Most of the traffic departs to the west and arrives from the east.) During January and February, when wind conditions force use of runway 9-27, the touch-and-go pattern is reversed.

Helipads 1, 2, and 3 are used for most helicopter flights. A pattern is used to the south when flights are not straight-in or -out. During January and February, when erratic wind conditions exist, rotary-wing aircraft may take off and land in any direction; however, heading 90 is used most often.

The helicopter paths in Figure 4 indicate that most rotary-wing traffic follows landmarks (such as roads and rivers) in transit to a specific training area. At this base, helicopters usually do not fly cross-country or over housing while in the confines of the reservation (except for VIP and medical transport which are examined later). The frequent use of landmarks by pilots makes the establishment of corridors relatively easy for noise impact prediction purposes, as discussed in the next section.

AIR TRAFFIC ACTIVITY LOG For use of this form, see AR 95-24; the proponent agency is ACSFOR.											DATE (Month and year)		
DAY OF MONTH	HOURS OF ACTIVITY	TYPE AIRCRAFT R-Rotary Wing F-Fixed Wing	AIR TRAFFIC ACTIVITY COUNT								TOTAL VFR (Sum of Columns d,f,h,j)	TOTAL IFR (Sum of Columns e,g,i,k)	TOTAL GCA (Included in Columns d thru k)
			LOCAL AIR TRAFFIC				ITINERANT AIR TRAFFIC						
			MILITARY		CIVIL		MILITARY		CIVIL				
			VFR	IFR	VFR	IFR	VFR	IFR	VFR	IFR			
a	b	c	d	e	f	g	h	i	j	k	l	m	n
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DA FORM 1968-R, 1 Sep 71 Replaces DA Form 1968-R, 1 Jan 69 which is obsolete.

Figure 2. DA Form 1968-R.

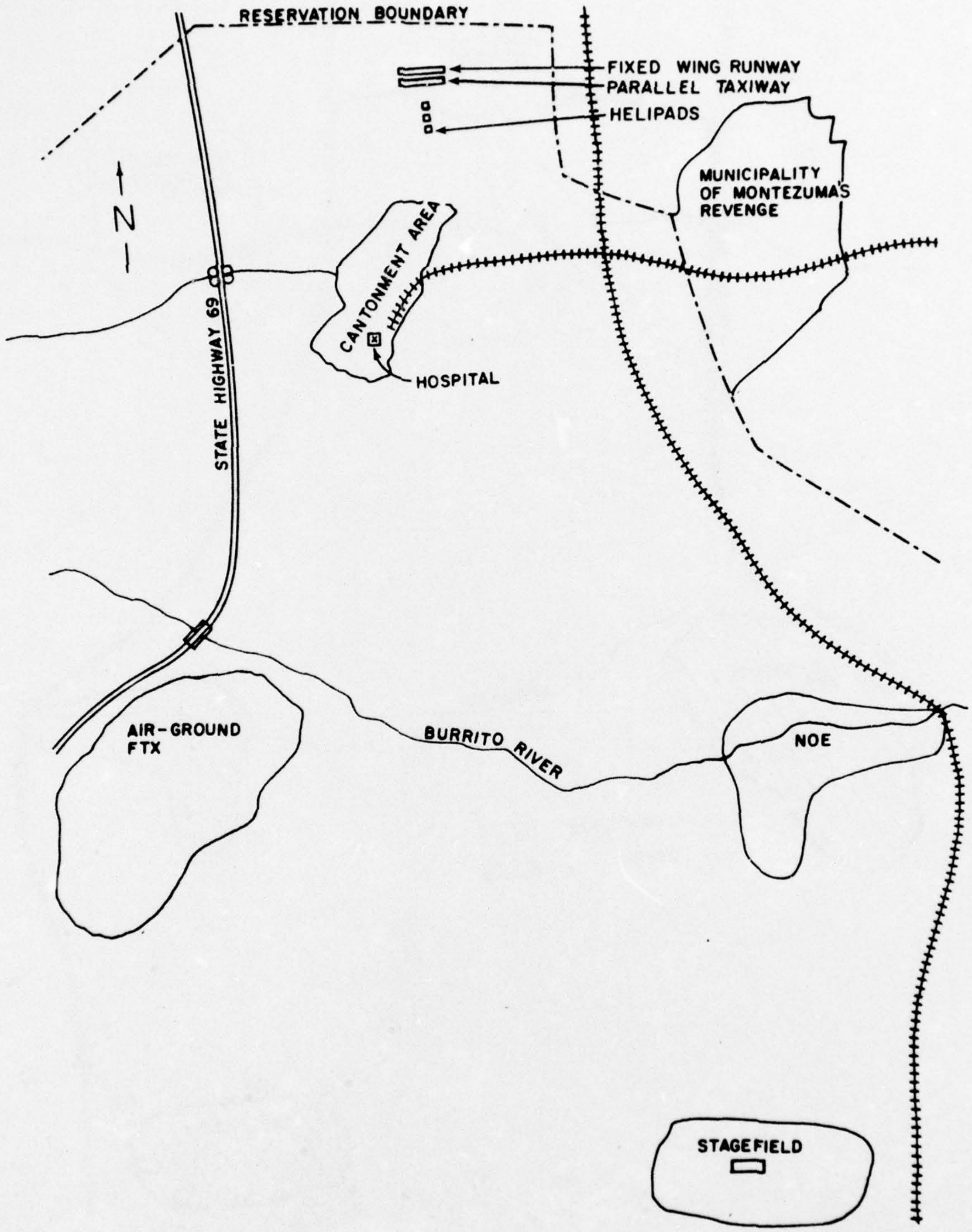


Figure 3. Training areas on Base X.

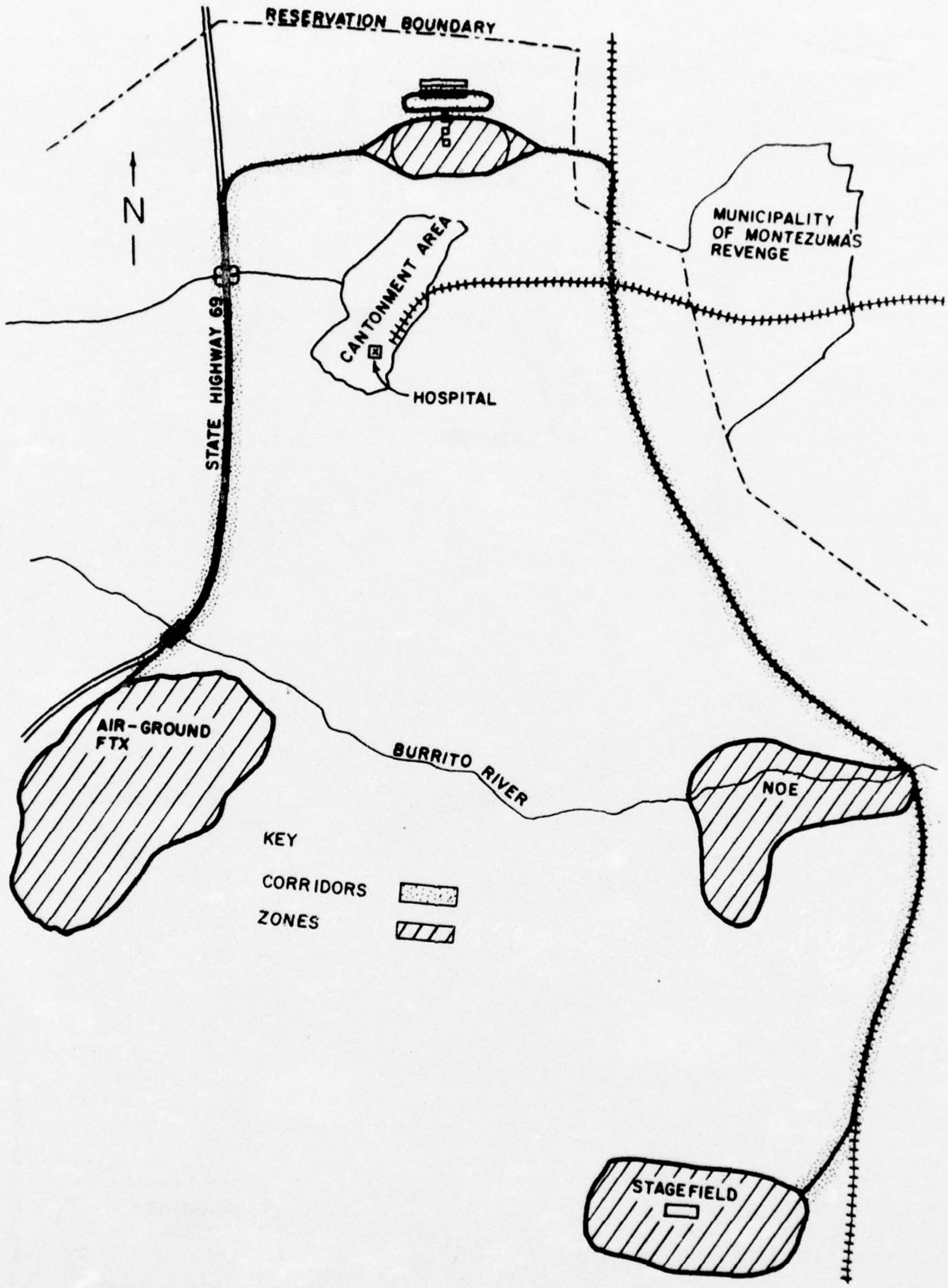


Figure 4. Corridors and zones on Base X.

Layout of Corridors and Zones

To identify those areas exposed to noise from rotary-wing aircraft operations, it is necessary to know where the noise sources (aircraft) are. An easy way to accomplish this is by defining nominal corridors for the operations. A corridor is a strip of space on the ground to both sides of the projection of aircraft passing overhead (ground track). Defining corridors is especially suited for rotary-wing aircraft, since landmarks are frequently used for navigation. The purpose is to have all aircraft that follow a particular route fall inside a corridor. Corridors also reflect anticipated or predicted traffic growth for an area. Cases where this requirement is especially applicable are at bases where a new unit or increase in operations under special conditions is expected. In these situations, corridors must be widened, altitudes increased, routes added, or a combination of these methods used, as appropriate.

It should be remembered that in all cases the purpose of corridors is not to restrict flight so that normal missions cannot take place. Rather, the purpose of establishing corridors is (1) to facilitate assessment of noise impact; (2) to aid planners in siting noise-sensitive structures, such as housing and barracks; and (3) to establish sufficient routes into and out of the airfield for present or predicted operations without impact (present or future) on noise-sensitive land uses or airfield operations. Figure 4 shows the corridors at the fictitious base.

It is recognized that corridors cannot be drawn for every foot that helicopters travel because of the nature of rotary-wing flight. For some types of activities that are removed from housing and other noise-sensitive land uses, drawing zones surrounding the activity is sufficient. Activities warranting this treatment are training courses and other large areas where description of helicopter flight by corridors is not possible. Figure 4 shows zones drawn around the Field Training Exercise (FTX), Nap of the Earth (NOE), and stagefield areas.* These zones represent the land overflown by most of the aircraft performing the activity. These zones, as explained before, are at best only good approximations, since occasional stray aircraft are impossible to chart. The planner must be aware of these unavoidable approximations.

*This discussion is an example only. At some bases, corridors may be the correct device to describe NOE training, stagefield work, etc.

Airfields and traffic patterns can be handled in two ways. First, if a pattern is small, about 1 mi (1.6 km) or less in diameter, a zone can be drawn around the pattern. On the other hand, a pattern may be treated as a corridor, with an average altitude of 300 ft (91 m) being used for calculation purposes. This case would be applicable for an extremely large pattern or one that might contain noise-sensitive land uses. The zone method should be applied if the pattern size varies greatly with helicopter type or wind conditions. Figure 4 shows a zone drawn around the helipad and their patterns, and a corridor system for the touch-and-go pattern.

Activities such as VIP transport and medical assistance are exceptions to the above rules for corridors and zones. For these activities, if the average daily number of operations is less than 10, no corridors should be drawn.

A review of the operations at the fictitious airfield and routes that pilots use will better illustrate how corridors are to be established.

Figure 4 shows the touch-and-go pattern for the parallel taxiway. No aircraft ever leave the touch-and-go pattern. During January and February, the winds change direction (from heading 270 to 90) and force the pattern in the opposite direction.

Stagefield training is performed south of the cantonment area. The principal route used to gain access to this area follows the railroad tracks, as shown in Figure 4. Aircraft normally depart from the helipad using the south pattern in order to get to the railroad corridor. Approaches are normally straight in from the railroad tracks 10 months of the year. January and February winds result in straight-out departures and pattern arrivals.

Aircraft for combined air-ground FTXs follow the highway west of the base to reach their destination. Westerly winds 10 months of the year mean that departures are straight-out and approaches use the south pattern from the helipad to get to the highway corridors. Easterly winds reverse approaches and departures. It should be mentioned that the pattern used for the helipad is not well defined primarily due to variable winds and differences in flight characteristics of different aircraft.

Calculation of Operations

Once corridors and zones have been created, the average number of daily operations per corridor and

zone should be approximated as a next step. An operation is defined as a takeoff or landing in a pattern or a fly-by in a corridor. A touch-and-go is counted as two operations. Initially, average daily operations should be recorded for corridors, the easiest of the two to chart.

Data for the corridors can be obtained from records kept at the control tower, pilot logs, visual counts taken in the corridor, or estimates by personnel familiar with operations at the airfield. Estimates are used for the example.

The number of operations is expressed in average daily units. This means that a typical month from the year is selected, and the total operations for that month divided by 30. This method produces an accounting of operations that reflects average conditions for an entire year.

Figure 5 shows present operations entered on the map for each of the corridors leading to the various activities shown. These operations were given by airfield personnel and further refined by observations in the field.

Knowing the traffic for corridors makes calculation of operations in the patterns somewhat simpler. Initially, it will be assumed that winds are always westerly. First, for the FTX air-ground route along the highway, the total average daily number of operations is known to be 70. It can be safely assumed that of these 70, 35 are departures and 35 arrivals. If the winds are westerly, then the 35 departures will be straight-out, taking off directly into the wind. The 35 arrivals will use the pattern for the helipad by making a 180-degree left turn south of the helipad and landing into the wind.

The NOE and stagefield routes along the railroad tracks are known to handle 160 average daily operations—50 for NOE and 110 for the stagefield. Dividing the 160 total operations into 80 arrivals and 80 departures, the 80 arrivals will be straight-in, directly into the wind. The 80 departures will take off to the west, then make a 180-degree left turn and proceed to the east.

Description of Altitude Profiles in Corridors

In order to calculate noise impact on the ground, one necessary factor is knowledge of altitude. Once average altitude and average daily operations are known, it is relatively easy to draw contours around corridors and zones* using data supplied in Table 1. Exact altitude, of course, is very difficult to ascertain, but average altitude can be obtained from personnel familiar with the airfield and its operations. Frequently, pilots will ascend, descend, or attain level flight when reaching ground landmarks.

Figure 6 shows the altitudes for the fictitious base. Transition points (change from an ascent or descent to level flight) are shown by bars perpendicular to the corridors. As can be seen, rotary-wing aircraft cruise at 1500 ft (457 m) AGL along the highway route and 1000 ft (305 m) along most of the railroad route. It should be remembered that larger aircraft have very different climb characteristics than others, thus necessitating consideration of average characteristics, such as climb and turning radius.

Separation of Corridors and Zones

As a next step, each corridor and pattern is divided into sections according to change in operations and change in altitude. Table 2 shows these changes corresponding to the numbered sections in Figure 7.

*Zones are discussed in detail in **Calculation of Noise Impact.**

Table 2

Average Daily Operations for Sections in Figure 7

Section No. (See Figure 7)	Altitude in ft AGL	Present Average Daily Operations*	Average Daily Operations for Calculation
1	zone**	60	100
2	zone	115	150
3	500 - 1500 (152 - 457 m)	70	100
4	500 - 1000 (152 - 305 m)	160	200
5	1500 (457 m)	70	100
6	1000 (305 m)	160	200
7	400 - 1000 (122 - 305 m)	110	150
8	400 (122 m)	110	150
9	zone	70	100
10	zone	50	100
11	zone	110	150

*Present average daily operations are raised to 100, 150, 200, or 300 operations to reflect average daily operations to be used for calculation.

**Zones are discussed in the next section.

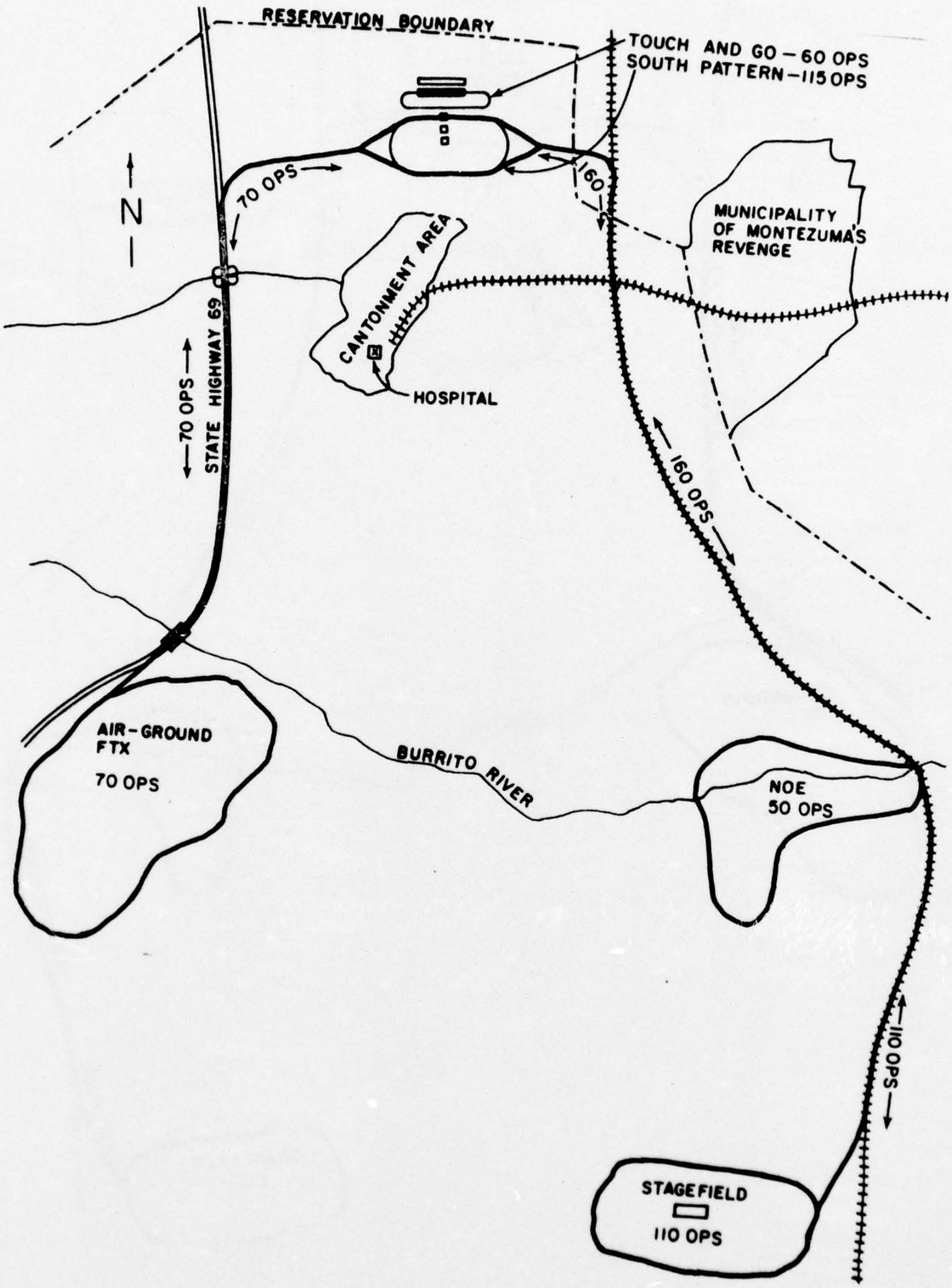


Figure 5. Average daily data for Base X.

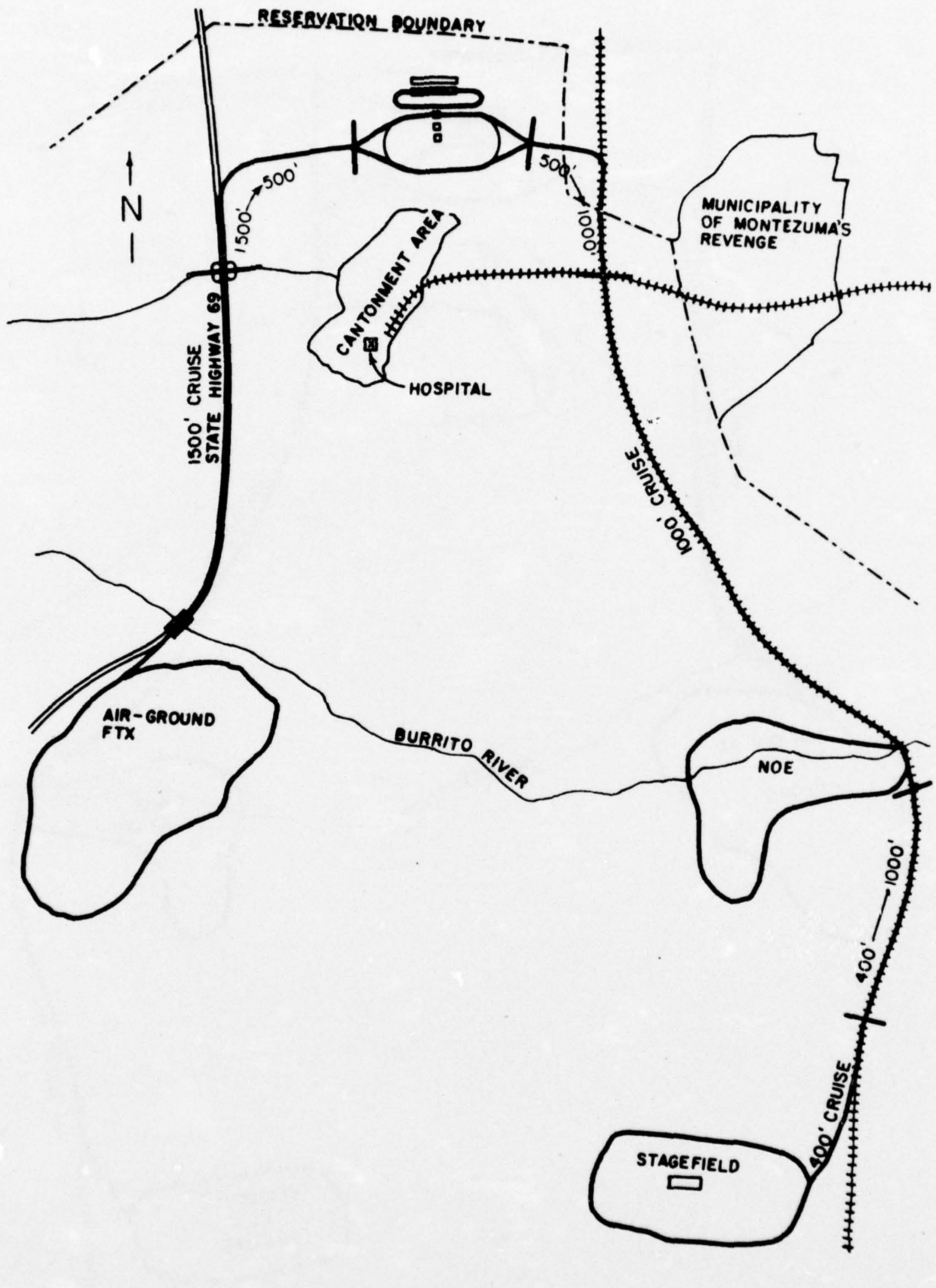


Figure 6. Altitude profiles for Base X.

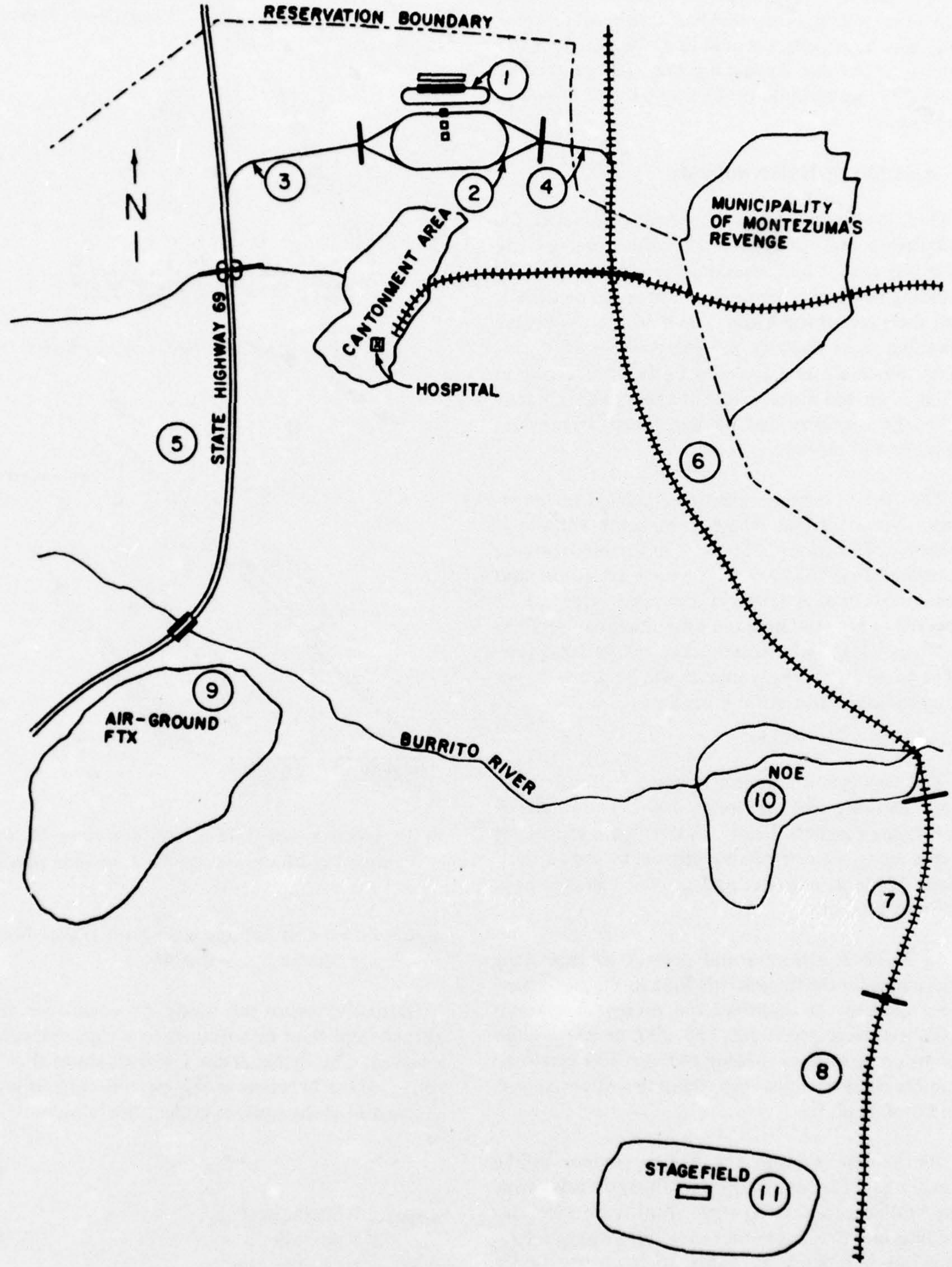


Figure 7. Numbering of corridor sections for Base X.

As a guide, if more than 15 sections have been created for a base, except for bases with hundreds of daily operations, effort should be made to reduce the number of sections. Reductions can be accomplished by simplifying altitude profiles or grouping nearby corridors.

Calculation of Noise Impact

Once the foregoing steps have been completed, the calculation and generation of noise contours are relatively easy. This calculation is accomplished by deciding which contour or contours are to be drawn, and then consulting Table 1 to find the applicable planning slant distance for the number of operations. Since altitude has already been recorded in Table 2, ground distance (the distance of the contour from the corridor) can be calculated from slant distance and altitude.

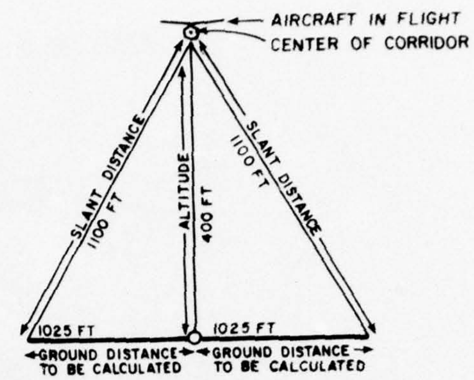
The 70 L_{dn} contour will be calculated for corridors. Those sections where a constant altitude is maintained (sections 5, 6, and 8 in Figure 7) will be examined first followed by sections of ascent and descent (sections 3, 4, and 7). For zones, areas where operations are scattered and unpredictable (sections 9, 10, and 11) will be examined as will patterns (sections 1 and 2). Finally, contours will be drawn as the culmination of the entire procedure.

Corridors—Level Flight

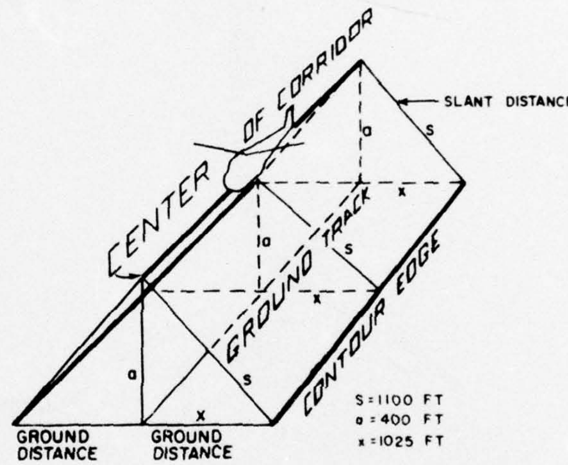
The concepts of ground distance, altitude, and slant distance can be more easily visualized by examining Figure 8. Point 0 in this figure represents a spot along the corridor directly below the aircraft. Slant distance, altitude, and ground distance have all been labeled.

In Table 2, altitudes and present average daily operations for the sections (defined in Figure 7) have been entered. In addition, the present operations have been increased to 100, 150, 200, or 300 to allow for future growth or mission change. The increased numbers of operations correspond to sections a, b, c, and d of Table 1.

As the first example, the 70 L_{dn} contour will be calculated for section 8, the level flight corridor from the NOE area to the stagefield. Noting from the last column in Table 2 that there are 150 average operations on this corridor, Table 1b is chosen as the correct data source. It is found that for an L_{dn} of 70, 150 operations give a planning slant distance of 1100 ft (335 m).



a. Head-on view of helicopter in flight.



b. Perspective view showing altitude slant distance, center of corridor, and the contour lines paralleling the corridor.

Figure 8. View of helicopter in level flight. Metric conversion factor: 1 ft = 0.3048 m.

Ground distance can easily be calculated from altitude and slant distance, since a right triangle is involved. The Pythagorean Theorem states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the remaining two sides or:

$$a^2 = b^2 + c^2$$

where a = Slant distance
b = Altitude
c = Ground distance.

Substituting the numbers from this example and solving for ground distance gives

$$c = \sqrt{1100^2 - 400^2}$$

$$c = 1025 \text{ ft } (312 \text{ m}) \text{ ground distance}$$

Alternately, the tables or figures in the appendix can be used to find ground distance if number of average daily operations and altitude are known. Using these charts or graphs eliminates the need for calculation.

To find the ground distance for the 70 L_{dn} contour with 150 average operations at an altitude of 400 ft (122 m), Table A2b is consulted; 1025 ft (312 m) is the correct ground distance. If desired, Figure A2b can be used similarly to obtain the same result. It should be noted that when using the appendix, Table 1 is not consulted and slant distances are not used. All examples in the text are explained using Table 1 and the concept of slant distance; the reader can verify these examples by using the appendix.

The distance of the L_{dn} 70 contour from the center of the corridor is 1025 ft (312 m). The contour can be drawn easily by measuring 1025 ft (312 m) from the center of section 8 at several locations and drawing a pair of lines paralleling the original corridor.

Section 6 is done in the same fashion. For 200 operations, Table 1c is consulted. To calculate the L_{dn} 70 contour, a 1350-ft (411 m) planning slant distance is used. Letting the altitude equal 1000 ft (305 m) and the slant distance be 1350 ft (411 m), the ground distance can be found to be 907 ft (276 m).

Section 5 is begun similarly; for 100 operations, Table 1a is consulted. To calculate L_{dn} 70, an 800-ft (244 m) planning slant distance is used. However, consideration of this situation indicates that the slant distance is actually shorter than the altitude, which means that there is no noise impact for the 70 L_{dn} contour.

Corridors—Altitude Transition

Slightly more calculation is required for ascents or descents. Section 7 from Figure 7 will be used as an example. Figure 9a shows a side view of the change in altitude from 400 to 1000 ft (122 to 305 m) AGL. It will be assumed that this change in altitude is one segment and aircraft are climbing/descending at a constant rate.

Since the average number of daily operations is 150, Table 1b is used to determine that an L_{dn} of 70 produces a slant distance of 1100 ft (335 m). The two end points, 400 ft (122 m) AGL and 1000 ft (305 m) AGL are shown from a head-on view in Figures 9b and c, as for the previous example. Two sets of ground distances, one for 400 ft (122 m) AGL and one for 1000 ft (305 m) will be calculated.

The first part of the change in altitude (400 ft [122 m] altitude) can be calculated using the previous equation with 1100 ft (335 m) as the slant distance and 400 ft (122 m) as the altitude. This gives:

$$c = \sqrt{1100^2 - 400^2}$$

$$c = 1025 \text{ ft } (312 \text{ m}) \text{ ground distance}$$

The last part of the change in altitude (1000 ft [305 m] altitude) is also easily calculated. Again using the slant distance of 1100 ft (335 m) the ground distance is 458 ft (140 m).

The drawn 70 L_{dn} contours for section 7 are shown in Figure 9d. At the point on the ground where 400 ft (122 m) AGL altitude is attained, 1025 ft (312 m) (the ground distance) is measured perpendicular to the center of the corridor. In like fashion, 458 ft (140 m) ground distance is measured perpendicular to the center of the corridor where 1000 ft (305 m) AGL altitude is attained. Straight lines are then drawn connecting the measured points on both sides of the corridor to generate two contours, as shown in Figure 10.

The 70 L_{dn} contours for section 4 are calculated in the same way. Consulting Table 1c for 200 average operations, a 1350-ft (411 m) slant distance is used. Since aircraft change altitude from 500 to 1000 ft (152 to 305 m) AGL, two calculations are required, producing ground distances of 1254 and 907 ft (382 and 276 m) respectively for the two altitudes.

Ascending and descending turns can also be handled using this method. As an example, a right turn ascending from 400 to 1000 ft (122 to 305 m) will be considered. It will be assumed that there are 150 operations and that the 70 L_{dn} contour is desired. From Table 1b, it is seen that a slant distance of 1100 ft (335 m) is to be used.

The distances to the contour edge are calculated in a manner similar to section 7 as described above; that is, the end points of 400 and 1000 ft (122 and 305 m) AGL altitude yield ground distances of 1024 and 458 ft (312 and 140 m) respectively. However,

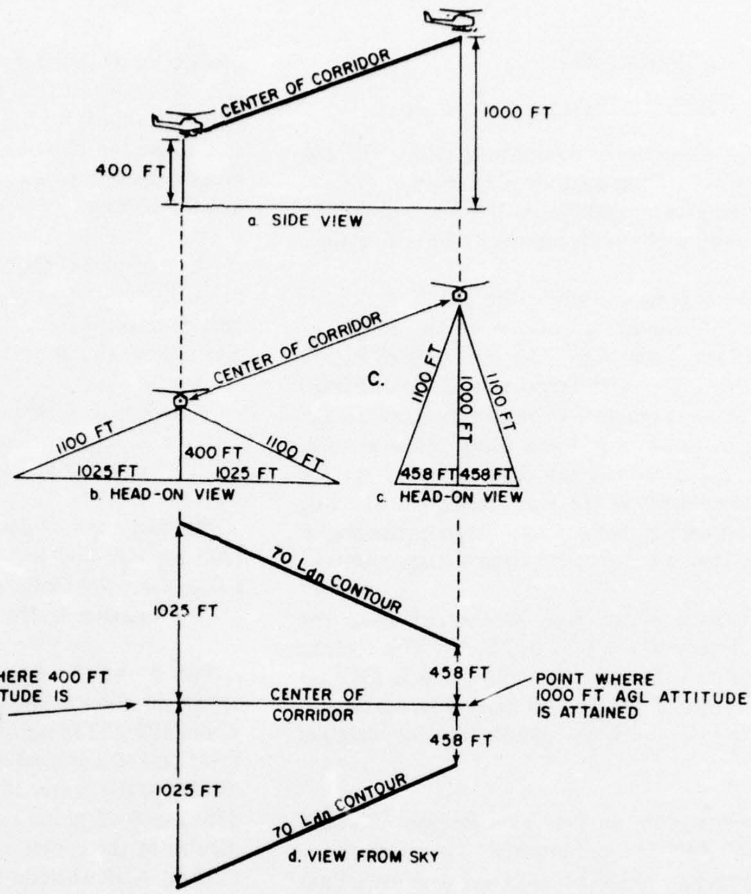


Figure 9. Calculating contours for ascents and descents for section 7. Metric conversion factor: 1 ft = 0.3048 m.

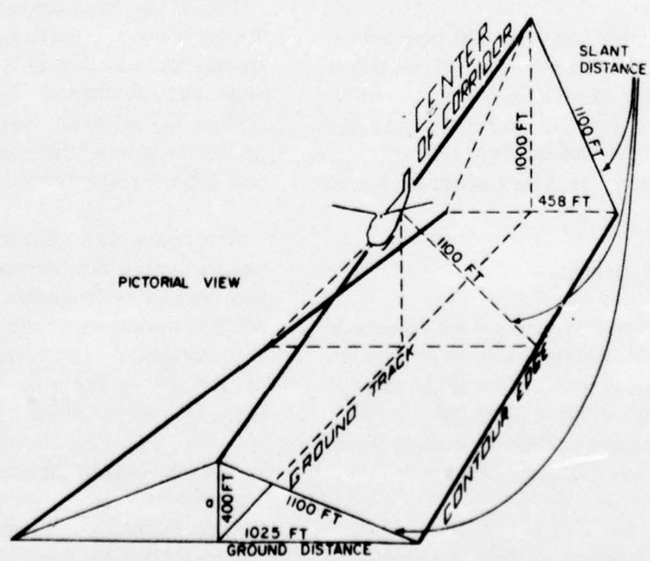


Figure 10. Change in contour width with altitude. Metric conversion factor: 1 ft = 0.3048 m.

more points should be calculated along a curved section for greater accuracy. This entails dividing the curved corridor into thirds and calculating the ground distance for the extra two points. For the example, the 90-degree right turn has been trisected at the points where 600 and 800 ft (183 and 244 m) AGL are assumed to be attained. Ground distance is then calculated using Table 1b, yielding 922 and 755 ft (281 and 130 m) for the two points. The 70 L_{dn} contours are then drawn by measuring ground distance perpendicular to the curve and connecting the measured points, as has been done in Figure 11.

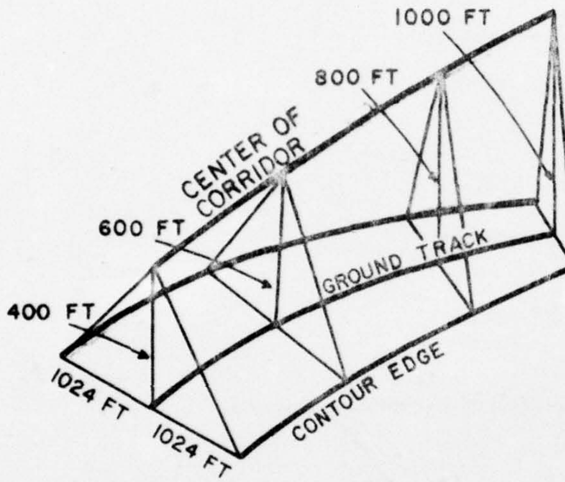


Figure 11. Perspective view of an ascending turn. Metric conversion factor: 1 ft = 0.3048 m.

For sharp (substantially in excess of the standard 3-degree/sec turn) turn segments of 90 degrees or less, a straight contour can be drawn on the inside of the turn connecting the two contour end points, as has been done in Figure 12. Straight line segments should not be drawn for turn segments in excess of 90 degrees. It should be noted that for calculation purposes, a turn should be divided into more than three sections when the turn segment exceeds 90 degrees.

Calculating contours for section 3 is slightly more difficult than for sections 4 through 8. There are 100 average daily operations with an altitude change from 500 to 1500 ft (152 to 456 m) AGL. Using a slant distance of 800 ft (244 m) from Table 1a, the lower altitude gives a ground distance of 624 ft (190 m). The higher altitude gives no noise impact for the 70 L_{dn} contour or, in other words, the contour is

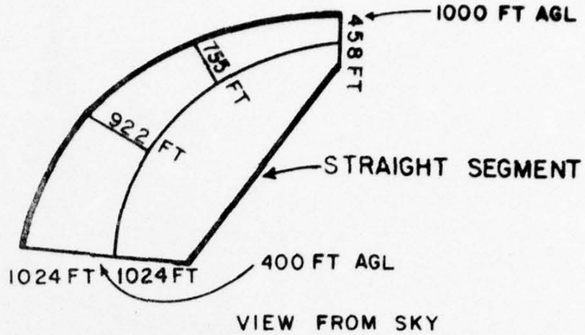


Figure 12. Straight segment drawn on inside of turn. Metric conversion factor: 1 ft = 0.3048 m.

coincident with the corridor, as was the case for section 5.

Figure 13a was drawn to find where the contour and corridor first coincide. Although slightly exaggerated in the drawing, a ground distance of 0 ft begins when the altitude is first equal to the slant distance, i.e., at 800 ft (244 m) AGL.

Figure 14 also illustrates where the contour and corridor coincide. Since the ascent is presumed to be at a steady rate, 800 ft (244 m) altitude is attained approximately one-third of the way between 500 and 1500 ft (152 and 456 m) AGL. This contour can then be drawn on a map, as in Figure 7, to reflect a ground distance of 624 ft (190 m) where the aircraft is first at 500 ft (152 m) AGL and then decreasing to 0 ft one-third of the way between 500 ft (152 m) and 1500 ft (456 m) AGL along the corridor.

Zones

Zones where helicopters are flying in an unpredictable manner (as in sections 9, 10, and 11) can be handled very simply. If these activities take place in an area remote from noise-sensitive land uses, effort expended in charting individual routes and calculating noise impact for each activity would certainly be wasted. Therefore, placing these activities in zones saves time without a loss in accuracy. A buffer area surrounding each zone provides an adequate margin for increased activity or mission change inside the zone.

Drawing contours around zones 9, 10, and 11 (the FTX, NOE, and stagefield areas) is very simple. Consulting Table 3, a buffer area of 693 ft (211 m) is to be drawn around zones to reflect L_{dn} 70 (NEF 35) contours. For L_{dn} 65 (NEF 30) the buffer area would

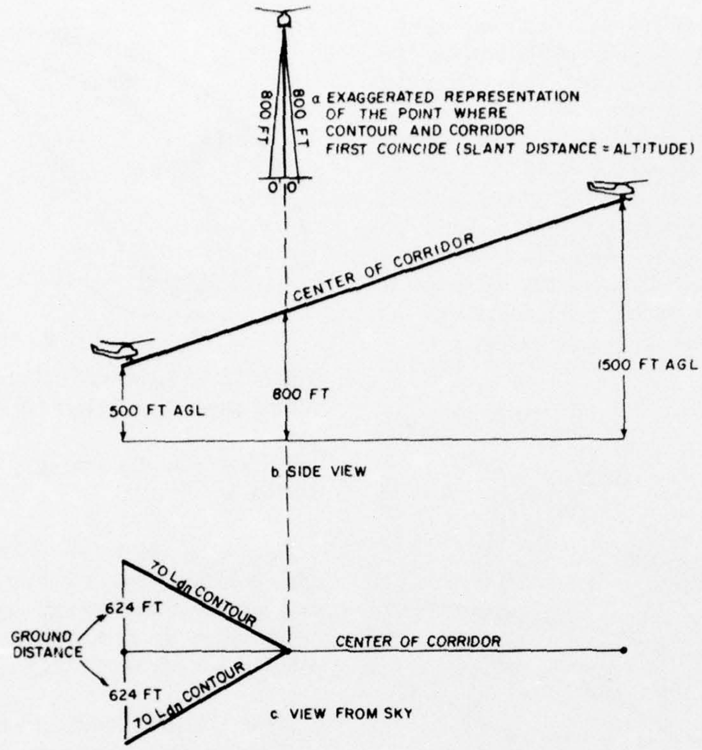


Figure 13. Calculating contours for ascents and descents for section 3.

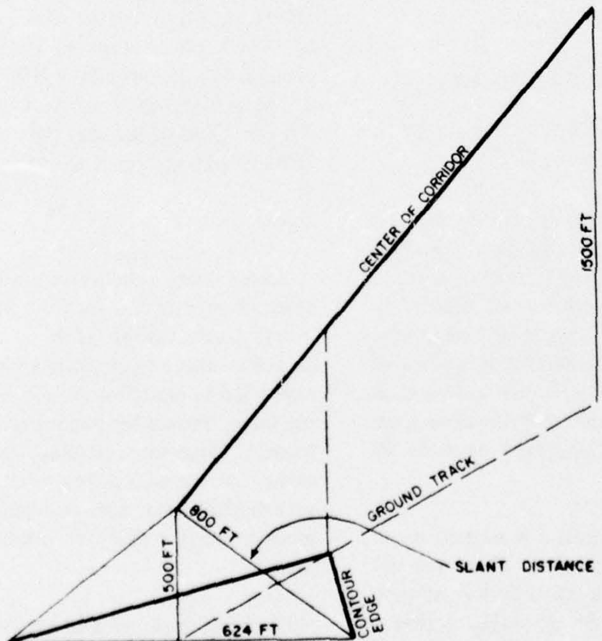


Figure 14. Pictorial for ascents and descents showing the point where contour and ground track coincide. At this point, the altitude equals the slant distance. Metric conversion factor: 1 ft = 0.3048 m.

Table 3

Calculated Ground Distances for Buffer Areas Drawn Around Remote Zones Where Helicopters Are Flying in an Unpredictable Manner*

NEF	L_{dn}	Planning Ground Distance
35	70	693 ft (211 m)
30	65	1755 ft (535 m)

*This table gives recommended ground distances rather than slant distances and is not intended for extremely large numbers of operations, such as 300 or more. CERL should be consulted before applying the criteria in such cases.

be 1755 ft (535 m). This buffer area will provide sufficient protection for moderate future growth.

Airfields are to be handled differently. If zones have been selected to be used around patterns where the operations are scattered, the following procedure should be used. The buffer area can be ascertained by finding the average daily operations for calculation from Table 2 and then using the appropriate chart from Table 4 for the ground distance. For the helipad pattern (section 2 in Figure 7), the average number of daily operations is 150 (Table 2). Table 4b reveals that a 1058-ft (322 m) buffer should be drawn around the zone for L_{dn} 70.

If the corridor method for airfields has been chosen because flight paths are fairly predictable, or if the pattern is large, the same method can be used; that is the number of operations is found from Table 2 and the correct chart is chosen from Table 4 to produce the buffer ground distance. The touch-and-go pattern (section 1 in Figure 7) has a buffer ground distance of 742 ft (226 m) for an L_{dn} value of 70, since there are 100 average daily operations.

Noise Impact Map

Figure 15 is a map of Base X with 70 L_{dn} contours drawn according to the procedures explained above. Normally, two or more sets of contours are included on one map to show greater degrees of noise impact. This has been accomplished in Figure 16 using the DOD-defined AICUZ zones described in Chapter 3. Zone 3 is depicted by the darkest shading, has the largest noise impact on people, and represents L_{dn} values above 75. Zone 2, shown by lighter shading, does not have as great an impact and represents values of 65 through 75 L_{dn}. All land outside Zone 2

Table 4

Calculated Ground Distances for Buffer Areas Drawn Around Airfield Zones and Corridors Close to Populated Areas*

NEF	L_{dn}	Planning Ground Distance
a. 100 Average Daily Operations		
40	75	125 ft (38 m)
35	70	742 ft (226 m)
30	65	1775 ft (541 m)
b. 150 Average Daily Operations		
40	75	400 ft (122 m)
35	70	1058 ft (322 m)
30	65	2381 ft (726 m)
c. 200 Average Daily Operations		
40	75	491 ft (150 m)
35	70	1316 ft (401 m)
30	65	2935 ft (895 m)
d. 300 Average Daily Operations**		
40	75	687 ft (209 m)
35	70	1826 ft (557 m)

*This table gives recommended ground distances rather than slant distances because a standard altitude of 300 ft (91 m) AGL has been assumed for operations in zones and corridors close to populated areas.

**This procedure is not intended for extremely large numbers of operations, such as 300 or more. CERL should be consulted before applying these criteria in such cases.

is unshaded and is zone 1. This largest area represents L_{dn} values below 65.

It should be noted that Zone 3 is not necessarily present everywhere that helicopters fly. Zone 2 need not be present if helicopters fly high enough or the operations are few.

5 CONCLUSION AND RECOMMENDATIONS

Conclusion

This report presents a method to determine noise impact generated by helicopter operations on and adjacent to military installations. In addition, the report contains criteria to be used for determining the siting of noise-sensitive facilities or for structuring new or modifying existing helicopter traffic corridors to avoid noise impact on sensitive areas. It is

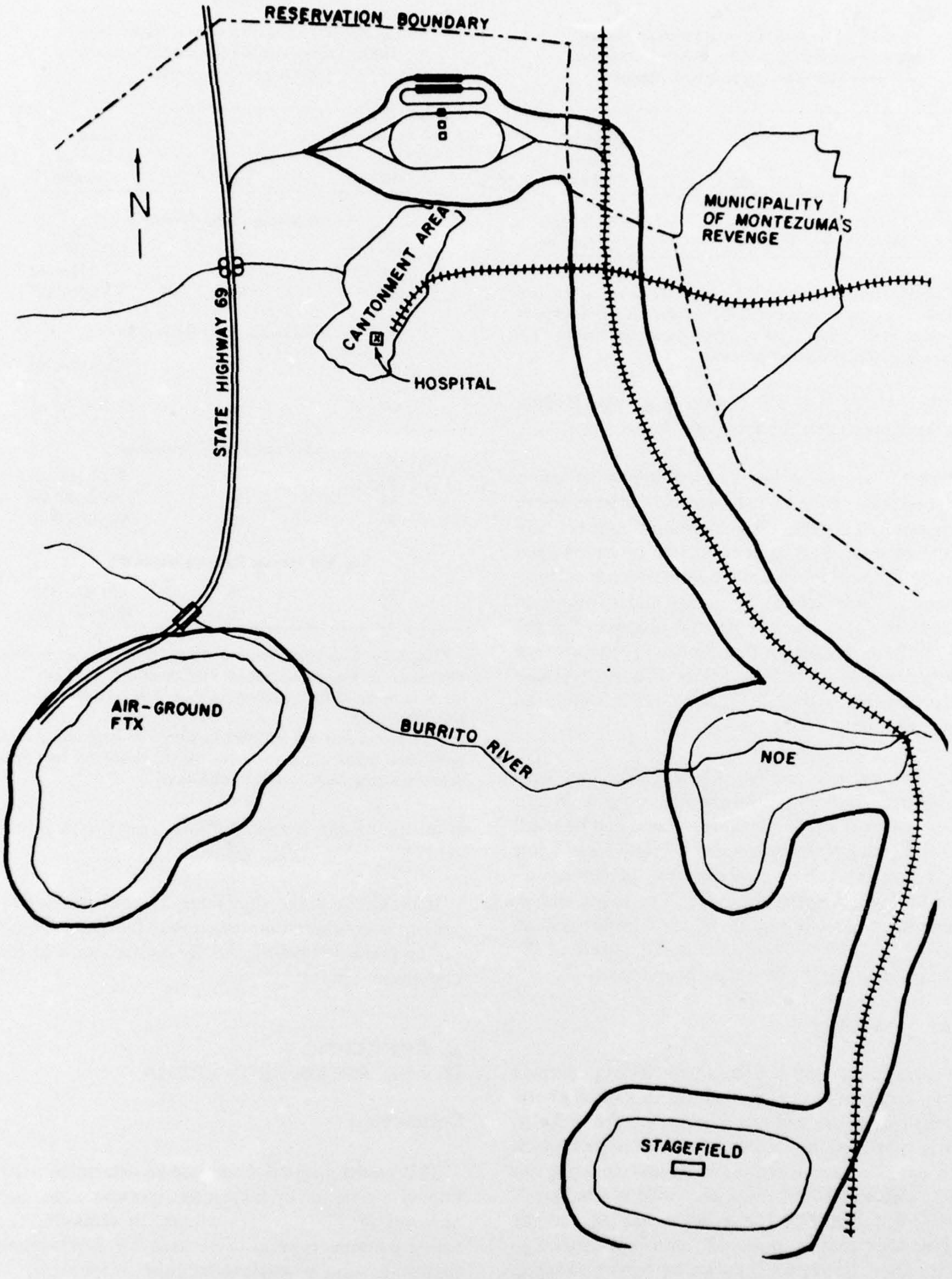


Figure 15. Noise impact map for L_{dn} value of 70.

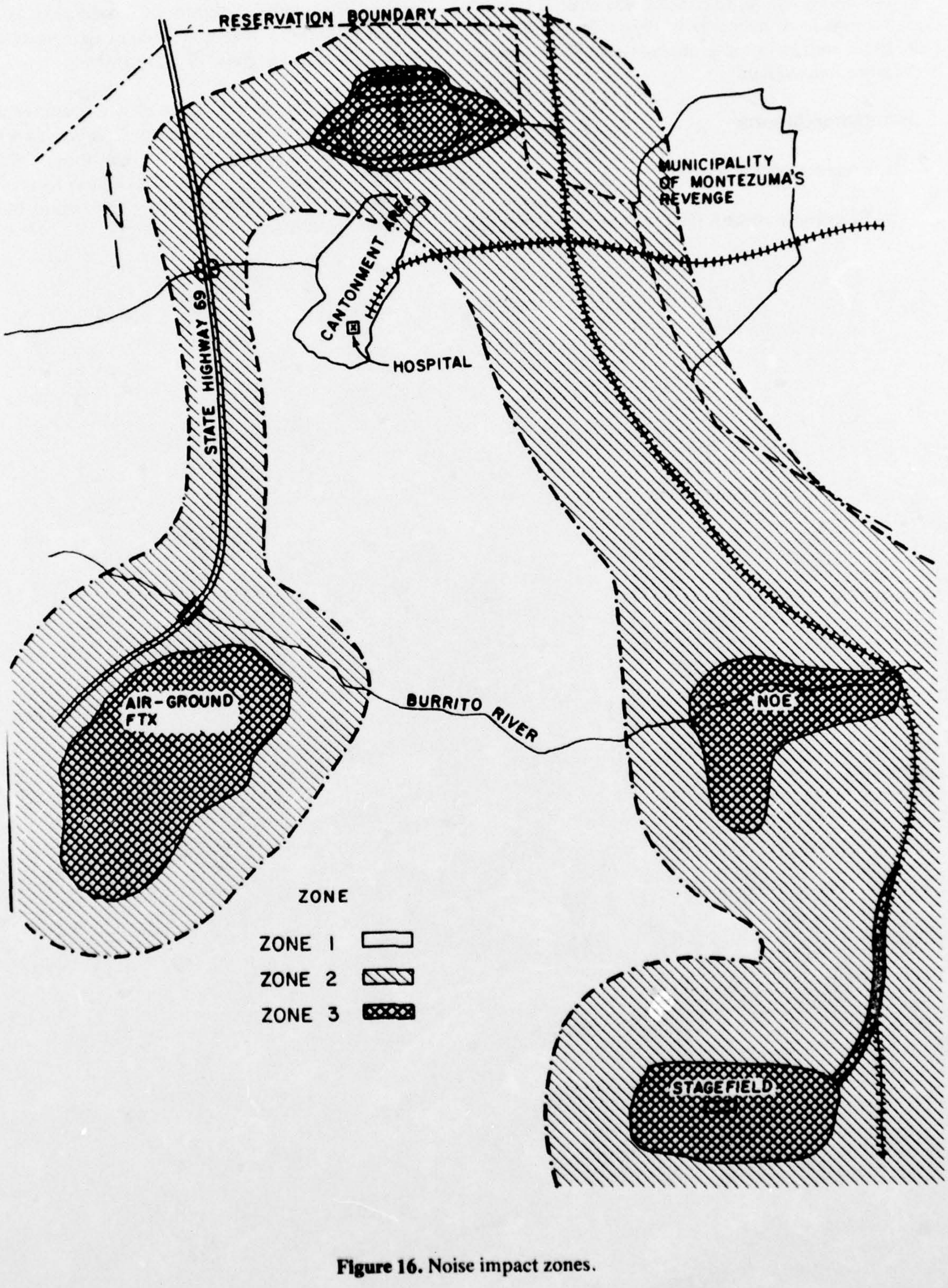


Figure 16. Noise impact zones.

recognized that the data and criteria in this report are an initial step in addressing the noise problems characteristic of helicopters; they are therefore an interim solution to the problems until more precise data become available.

Recommendations

It is recommended that:

1. The procedures set forth in this user's manual be used by installation commands having helicopter units permanently assigned or commands which support training activities of military elements which have helicopters organic to their units.

2. These procedures be used for planning the proper siting of noise-sensitive facilities and the development of helicopter traffic corridors, and for implementing the DOD AICUZ program as may be appropriate to the civilian areas in the vicinity of the military installation.

APPENDIX:

CHARTS AND GRAPHS FOR DETERMINING GROUND DISTANCE

Table A1

Ground Distances for 100 Average Daily Operations*

a		b		c	
75 L_{dn}	40 NEF	70 L_{dn}	35 NEF	65 L_{dn}	30 NEF
Planning Slant Distance = 325 ft (99 m)		Planning Slant Distance = 800 ft (244 m)		Planning Slant Distance = 1800 ft (549 m)	
Altitude AGL ft (m)	Ground Distance ft (m)	Altitude AGL ft (m)	Ground Distance ft (m)	Altitude AGL ft (m)	Ground Distance ft (m)
325 (99)	0 (0)	800 (244)	0 (0)	1800 (549)	0 (0)
300 (91)	125 (38)	750 (229)	278 (85)	1700 (518)	592 (180)
275 (84)	173 (53)	700 (213)	387 (118)	1600 (488)	825 (251)
250 (76)	208 (63)	650 (198)	446 (142)	1500 (457)	995 (303)
225 (69)	235 (71)	600 (183)	529 (161)	1400 (427)	1131 (345)
200 (61)	256 (78)	550 (168)	581 (177)	1300 (396)	1245 (379)
175 (53)	274 (83)	500 (152)	624 (190)	1200 (366)	1342 (409)
150 (46)	288 (88)	450 (137)	661 (202)	1100 (335)	1425 (434)
125 (38)	300 (91)	400 (122)	693 (211)	1000 (305)	1497 (456)
100 (30)	309 (94)	350 (107)	719 (219)	900 (274)	1559 (475)
75 (23)	316 (96)	300 (91)	742 (226)	800 (244)	1612 (491)
50 (15)	321 (98)	250 (76)	760 (232)	700 (213)	1658 (505)
25 (8)	324 (99)	200 (61)	775 (236)	600 (183)	1697 (517)
0 (0)	325 (99)	150 (46)	786 (240)	500 (152)	1729 (527)
		100 (30)	794 (242)	400 (122)	1755 (535)
		50 (15)	798 (243)	300 (91)	1775 (541)
		0 (0)	800 (244)	200 (61)	1789 (545)
				100 (30)	1797 (548)
				0 (0)	1800 (549)

*Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

Table A2

Ground Distances for 150 Average Operations*

a		b		c	
75 L_{dn}	**40 NEF**	**70 L_{dn}**	**35 NEF**	**65 L_{dn}**	**30 NEF**
Planning Slant Distance = 475 ft (152 m)		**Planning Slant Distance = 1100 ft (335 m)**		**Planning Slant Distance = 2400 ft (732 m)**	
Altitude AGL ft (m)	**Ground Distance ft (m)**	**Altitude AGL ft (m)**	**Ground Distance ft (m)**	**Altitude AGL ft (m)**	**Ground Distance ft (m)**
475 (145)	0 (0)	1100 (335)	0 (0)	2400 (732)	0 (0)
450 (137)	152 (46)	1000 (305)	458 (140)	2200 (671)	959 (292)
400 (122)	256 (78)	900 (274)	632 (193)	2000 (610)	1327 (404)
350 (107)	321 (98)	800 (244)	755 (230)	1800 (549)	1587 (484)
300 (91)	368 (112)	700 (213)	849 (259)	1600 (488)	1789 (545)
250 (76)	404 (123)	600 (183)	922 (281)	1400 (427)	1949 (594)
200 (61)	431 (131)	500 (152)	980 (299)	1200 (366)	2078 (634)
150 (46)	451 (137)	400 (122)	1025 (312)	1000 (305)	2182 (665)
100 (30)	464 (142)	300 (91)	1058 (322)	800 (244)	2263 (690)
50 (15)	472 (144)	200 (61)	1082 (330)	600 (183)	2324 (708)
0 (0)	475 (145)	100 (30)	1095 (334)	400 (122)	2366 (721)
		0 (0)	1100 (335)	200 (61)	2392 (729)
				0 (0)	2400 (732)

*Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

Table A3

Ground Distances for 200 Average Daily Operations*

a		b		c	
75 L_{dn}	**40 NEF**	**70 L_{dn}**	**35 NEF**	**65 L_{dn}**	**30 NEF**
Planning Slant Distance = 575 ft (175 m)		**Planning Slant Distance = 1350 ft (411 m)**		**Planning Slant Distance = 2950 ft (899 m)**	
Altitude AGL ft (m)	**Ground Distance ft (m)**	**Altitude AGL ft (m)**	**Ground Distance ft (m)**	**Altitude AGL ft (m)**	**Ground Distance ft (m)**
575 (175)	0 (0)	1350 (41[illegible])	0 (0)	2950 (899)	0 (0)
550 (168)	168 (51)	1300 (396)	364 (111)	2800 (853)	929 (283)
500 (152)	284 (87)	200 (366)	618 (189)	2600 (792)	1394 (425)
450 (137)	358 (109)	100 (335)	783 (239)	2400 (731)	1715 (523)
400 (122)	413 (126)	1000 (305)	907 (276)	2200 (671)	1965 (599)
350 (107)	456 (139)	900 (274)	1006 (307)	2000 (610)	2169 (661)
300 (91)	491 (150)	800 (244)	1087 (331)	1800 (549)	2337 (712)
250 (76)	518 (158)	700 (213)	1154 (352)	1600 (488)	2478 (755)
200 (61)	539 (164)	600 (183)	1209 (369)	1400 (427)	2597 (791)
150 (46)	555 (169)	500 (152)	1254 (382)	1200 (366)	2695 (821)
100 (30)	566 (173)	400 (122)	1289 (393)	1000 (305)	2775 (846)
50 (15)	573 (175)	300 (91)	1316 (401)	800 (244)	2839 (865)
0 (0)	575 (175)	200 (61)	1335 (407)	500 (152)	2907 (886)
		100 (30)	1346 (410)	200 (61)	2943 (897)
		0 (0)	1350 (411)	100 (30)	2948 (899)
				0 (0)	2950 (899)

*Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

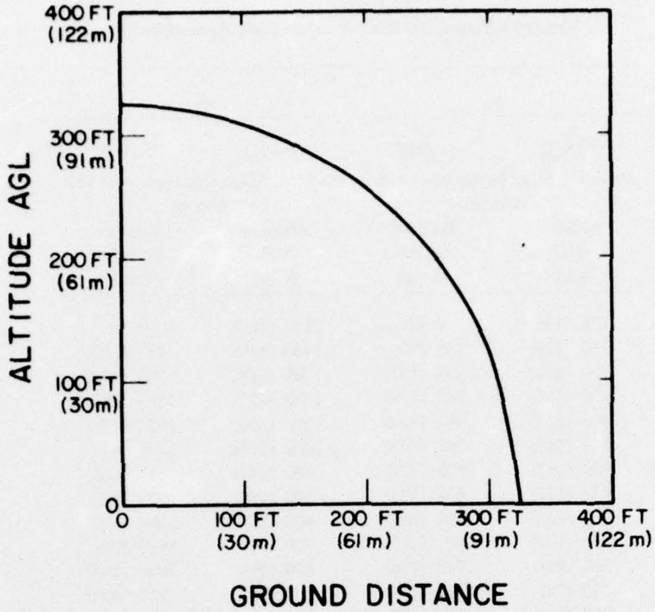
Table A4

Ground Distances for 300* Average Daily Operations**

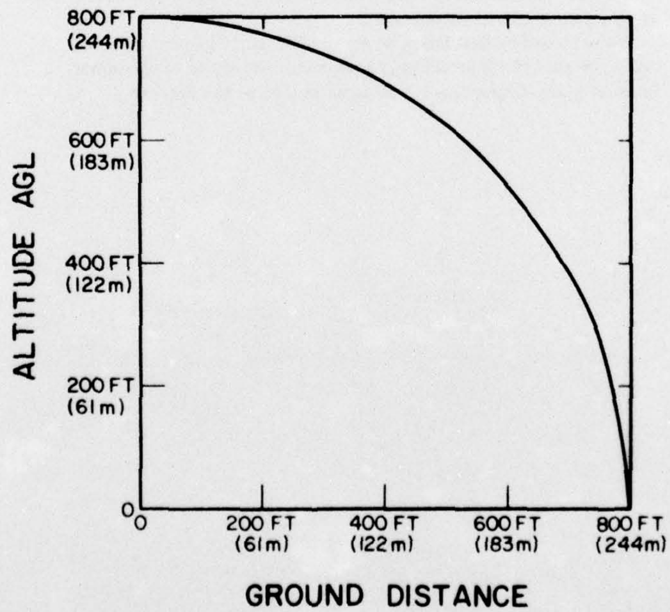
a		b	
75 L_{dn}	**40 NEF**	**70 L_{dn}**	**35 NEF**
Planning Slant Distance = 175 ft (236 m)		**Planning Slant Distance = 1850 ft (564 m)**	
Altitude AGL ft (m)	**Ground Distance ft (m)**	**Altitude AGL ft (m)**	**Ground Distance ft (m)**
775 (236)	0 (0)	1850 (564)	0 (0)
750 (229)	195 (60)	1800 (549)	427 (130)
700 (213)	333 (101)	1700 (518)	730 (222)
650 (198)	422 (129)	1400 (427)	1209 (369)
600 (183)	491 (150)	1200 (366)	1408 (429)
550 (168)	546 (166)	1000 (305)	1556 (474)
500 (152)	592 (180)	800 (244)	1668 (508)
450 (137)	631 (192)	600 (183)	1750 (533)
400 (122)	664 (202)	400 (122)	1806 (551)
350 (107)	691 (211)	200 (61)	1839 (561)
300 (91)	715 (218)	100 (30)	1847 (563)
250 (76)	734 (224)	0 (0)	1850 (564)
200 (61)	749 (228)		
150 (46)	760 (232)		
100 (30)	769 (234)		
50 (15)	773 (236)		
0 (0)	775 (236)		

*This procedure is not intended for extremely large numbers of operations, such as 300 or more. CERL should be consulted before applying these criteria in such cases.

**Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

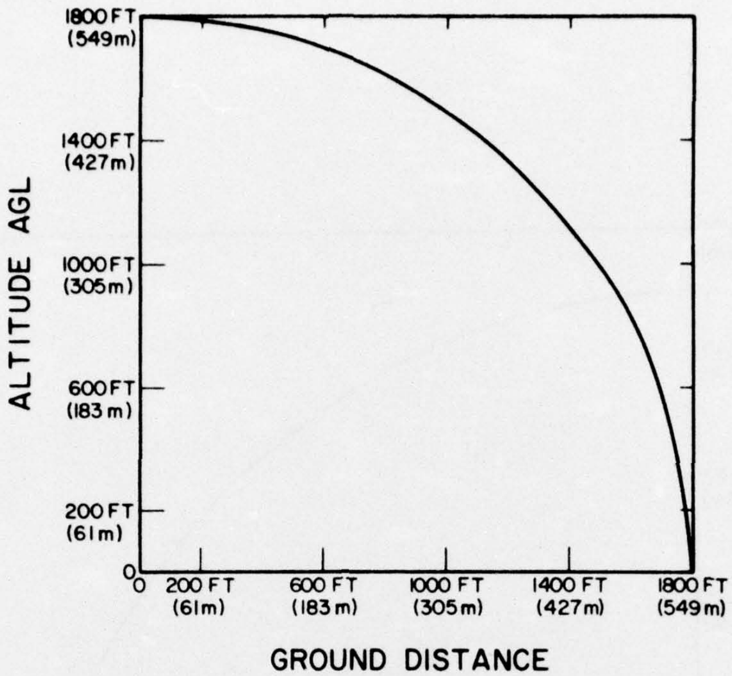


a. 75 L_{dn} 40 NEF.



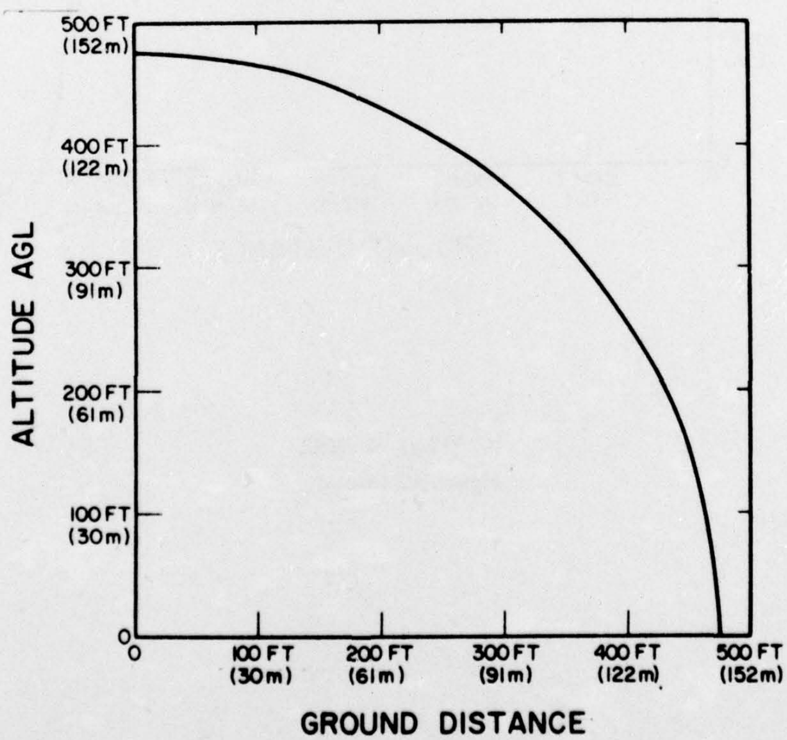
b. 70 L_{dn} 35 NEF.

Figure A1. Ground distance for 100 average daily operations.



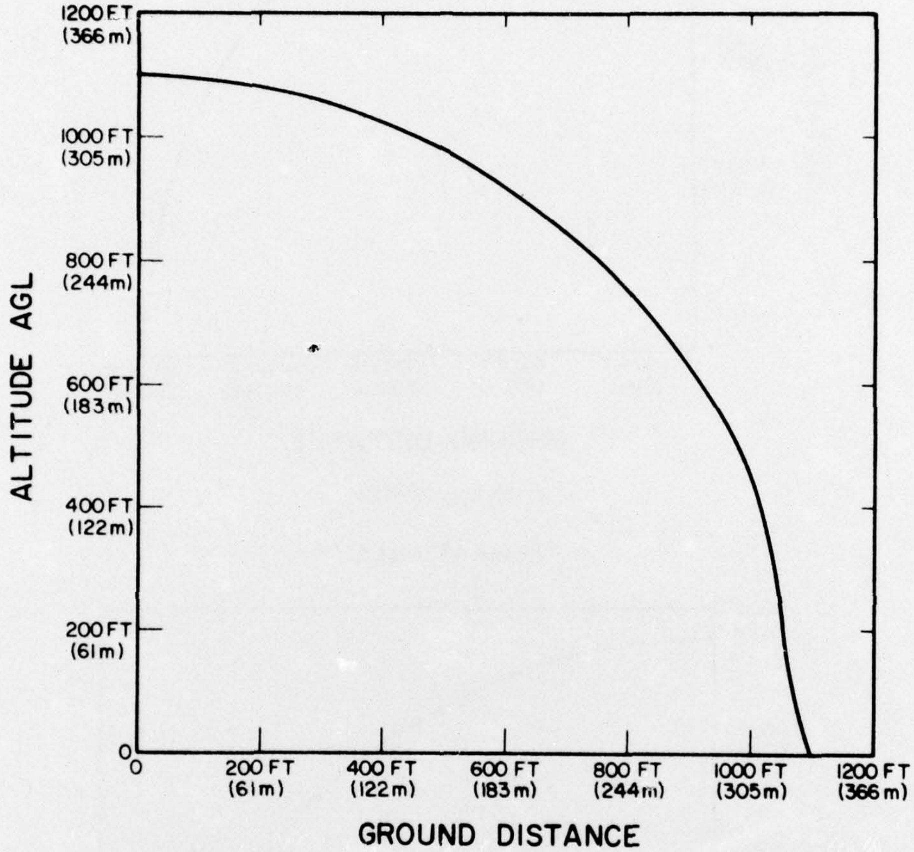
c. 65 L_{dn} 30 NEF.

Figure A1 (cont'd).



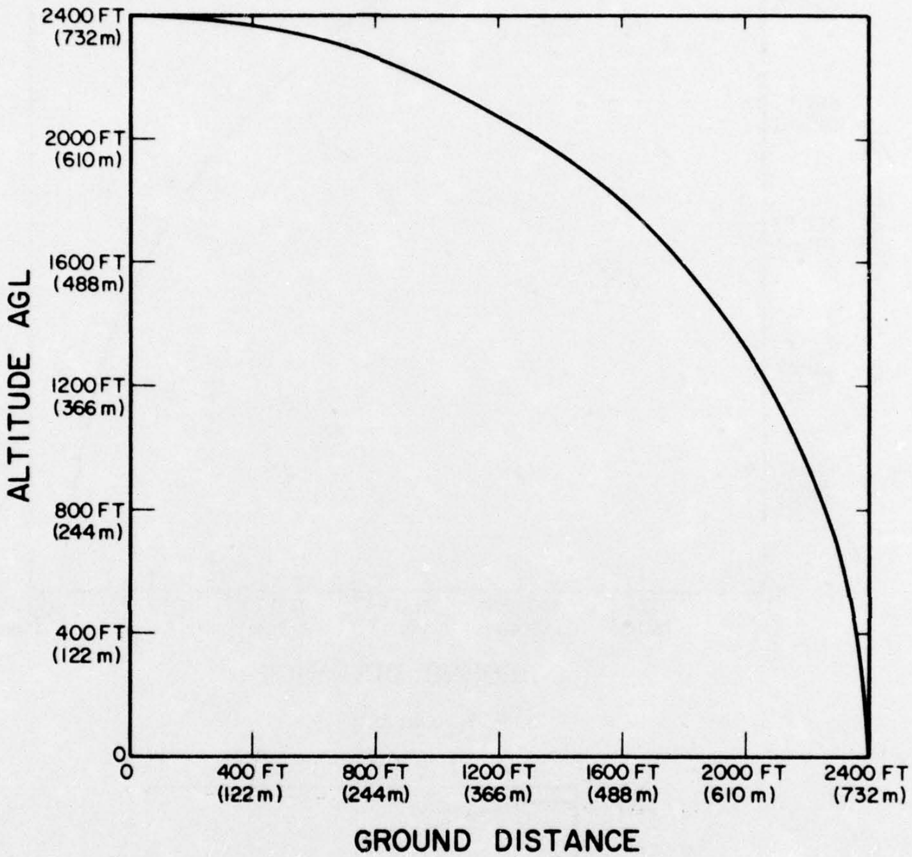
a. 75 L_{dn} 40 NEF.

Figure A2. Ground distance for 150 average daily operations.



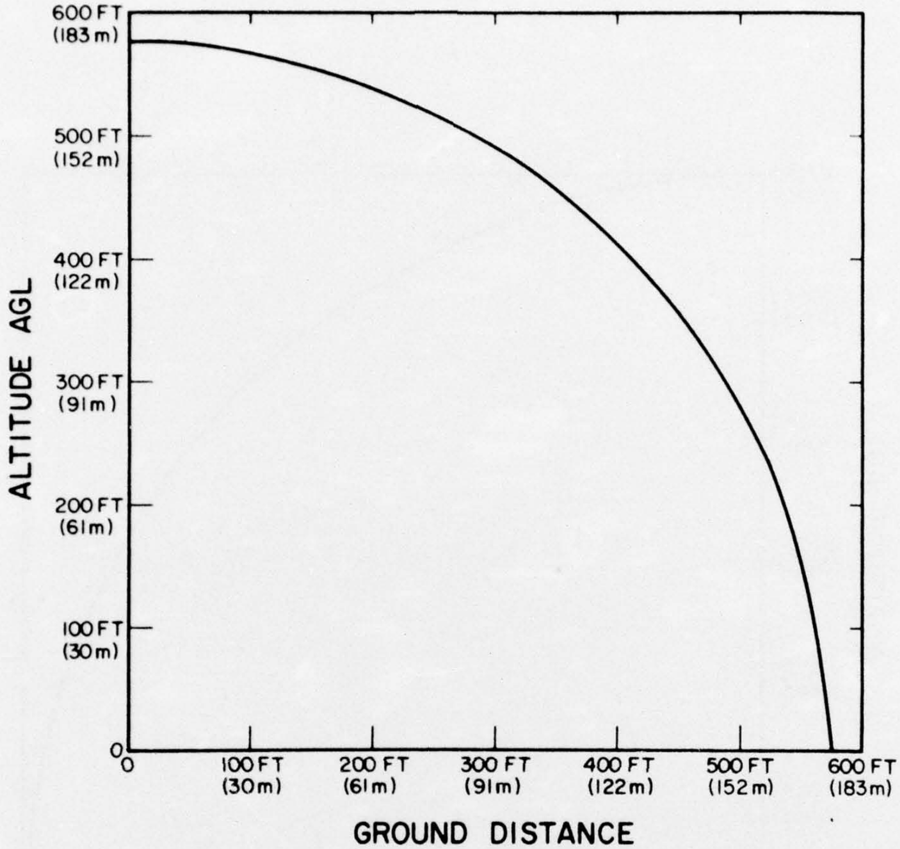
b. 70 L_{dn} 35 NEF.

Figure A2 (cont'd).

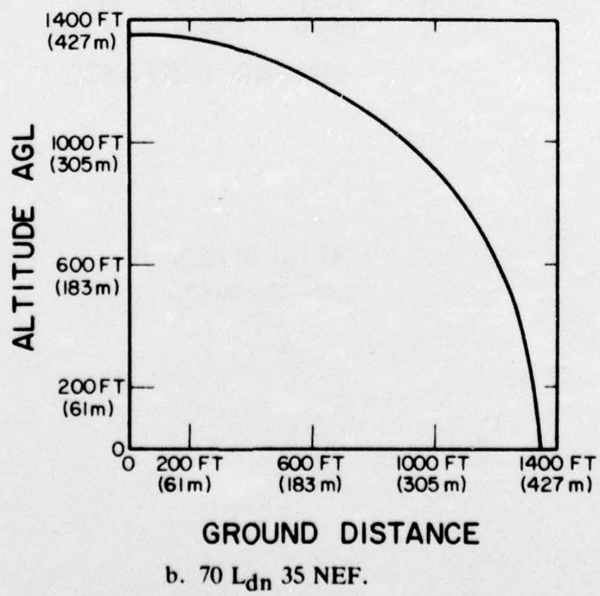


c. 65 L_{dn} 30 NEF.

Figure A2 (cont'd).

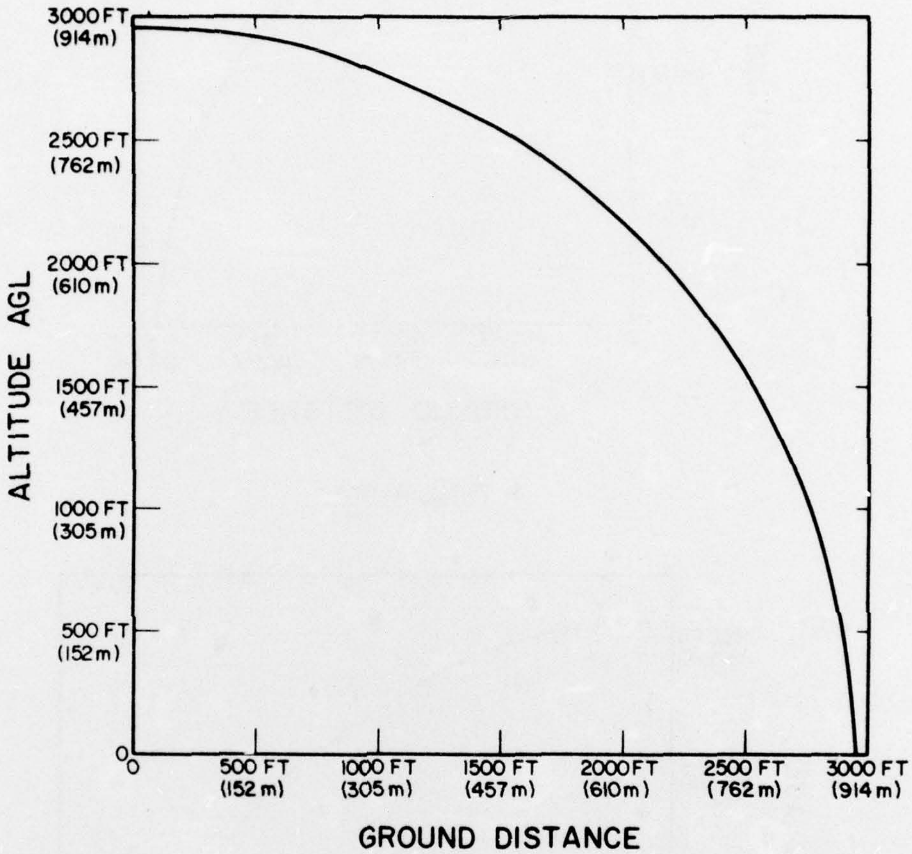


a. 75 L_{dn} 40 NEF.



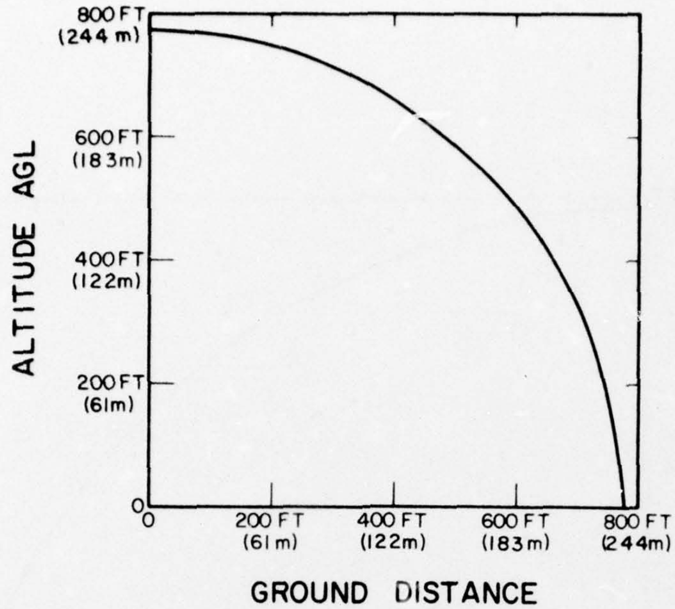
b. 70 L_{dn} 35 NEF.

Figure A3. Ground distance for 200 average daily operations.

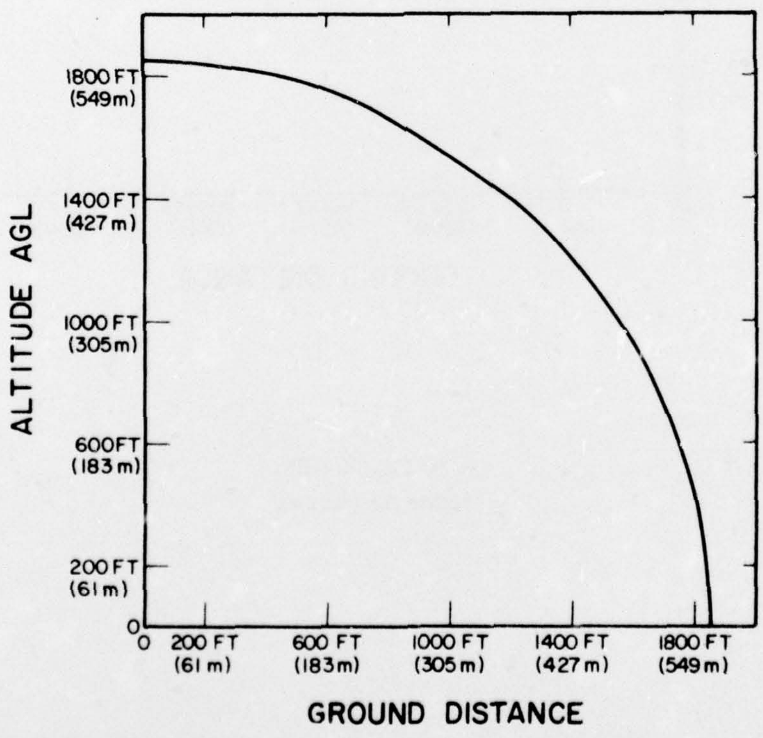


c. 65 L_{dn} 30 NEF.

Figure A3 (cont'd).



a. 75 L_{dn} 40 NEF.



b. 70 L_{dn} 35 NEF.

Figure A4. Ground distance for 300 average daily operations.

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